COMMITTEE ON GOVERNMENT REFORM

Subcommittee on Energy and Resources

DARRELL ISSA, CHAIRMAN

Oversight Hearing:

Rebalancing the Carbon Cycle

September 27, 2006, 2:00 pm
Rayburn House Office Building
Room 2154

BRIEFING MEMORANDUM

Summary

In 2004, the United States emitted about 5.7 billion more tons of carbon dioxide than could be processed by natural systems, such as trees, soils, and oceans. As a result, concentrations of carbon dioxide in the atmosphere are rising, potentially increasing the risk of climate change. The carbon cycle, or the flow of carbon between the atmosphere, land, oceans, and plants, could be rebalanced by (1) emitting less carbon dioxide by burning less fossil fuels, and (2) capturing and storing carbon dioxide produced by burning fossil fuels. A diverse range of approaches are necessary to rebalance the carbon cycle, including improved energy efficiency and the production of more electricity with nuclear power and renewable resources.

Background

The United States emitted 6.6 billion tons of carbon dioxide in 2004, primarily due to the combustion of fossil fuels, including coal, oil, and natural gas for electricity production, industrial processes, and transportation.[1] Electricity production was responsible for about 38 percent of carbon dioxide emissions in 2004. Land use changes, such as increases in the amount of forest productivity, removed about 860 million tons of carbon dioxide from the atmosphere through natural processes.[2] As a result, in 2004, the United States emitted about 5.7 billion more tons of carbon dioxide than natural systems could absorb, affecting the delicately balanced carbon cycle that flows between the land, atmosphere, and oceans, and increasing the risk of potential changes to the climate system. According to the United States Climate Change Science Program, over the past

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[1] Environmental Protection Agency, *The U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990-2004*, (Washington DC, April 15, 2006).

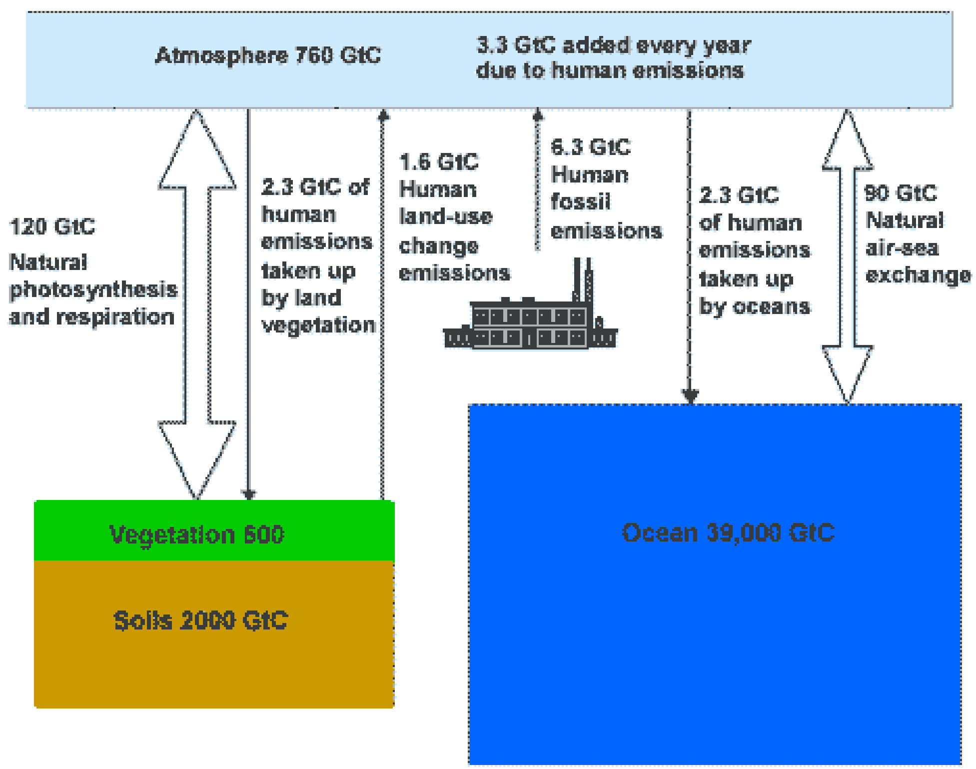
[2]EPA estimates do not include emissions sources without reliable estimation methods or emissions sources, such as volcanic eruptions and natural forest fires and sequestration activities, like the uptake of carbon dioxide by oceans, that are not a direct result of or influenced by human activities.

two centuries, fossil-fuel emissions, land-use change, and other human activities increased atmospheric carbon dioxide by 30 percent to concentrations unprecedented over the past 420,000 years.[3] Other countries are also contributing to the increased concentration of carbon dioxide in the atmosphere. According to the Energy Information Administration, the United States accounted for 21.7 percent of the world's carbon dioxide emissions from the consumption and flaring of fossil fuels in 2004.[4]

The Carbon Cycle

The carbon cycle consists of flows, or "fluxes" of carbon between storage reservoirs, or "sinks" including the atmosphere, oceans, and plants. For example, if a tree dies in a forest, the carbon stored in the tree is released through decomposition into the atmosphere. Some of the carbon released by the tree may be used by other vegetation as an input for photosynthetic growth, wind up in the ocean or soils through natural processes, or remain in the atmosphere. Figure 1 illustrates a simplified version of the global carbon cycle and the annual carbon fluxes between carbon sinks, including the impact of human-caused emissions from burning fossil fuels and land use changes.

Figure 1: Simplified Global Carbon Cycle Including Human-Caused Emissions



Large arrows represent natural, annual carbon fluxes. Small arrows represent human-induced, annual carbon fluxes. All numbers are in billion metric tons (Gigatons) of carbon (GtC). Numbers next to arrows represent annual carbon fluxes (GtC/yr). Numbers in boxes represent size of carbon reservoirs (GtC).

Source: Environmental Protection Agency, http://www.epa.gov/sequestration/ccyle.html, based on IPCC SRLULUCF 2000 and IPCC TAR WGI 2001

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[3] U.S. Climate Change Science Program, *Our Changing Planet: The U.S. Climate Change Science Program for Fiscal Year 2006*, (Washington DC, October 2005)
[4] http://www.eia.doe.gov/pub/international/iealf/tableh1co2.xls

Strategies to Rebalance the Carbon Cycle

The carbon cycle could be rebalanced by (1) emitting less carbon dioxide by burning less fossil fuels, and (2) capturing and storing carbon dioxide produced by burning fossil fuels.[5] Any single technology or method is unlikely to address the entire carbon imbalance by itself. A diverse set of approaches would provide greater flexibility to respond to new information or technological advances.

Reducing Carbon Dioxide Emissions

The United States can reduce carbon dioxide emissions from electricity generation by switching to less carbon-intensive fuels, such as nuclear power and renewable resources, or through energy efficiency activities to reduce the demand for electricity. Nuclear power and renewables, such as wind and solar power, have proven track records and emit no carbon dioxide. The combustion of natural gas and biomass, such as switchgrass, to produce electricity is also less carbon-intensive than fossil fuels. To the extent that such low-carbon alternatives replace fossil fuel generation, they may help reduce the imbalance in the carbon cycle. Potential drawbacks of nuclear power include the lack of nuclear waste storage or reprocessing capacity and high construction costs. Some weaknesses of renewable resources are that they produce intermittently and are often sited far from populated areas and therefore require significant investments in electricity transmission infrastructure. Increased energy efficiency could also reduce the demand for electricity and decrease the associated carbon dioxide emissions.

Carbon Sequestration

There are two types of carbon sequestration, including (1) human engineered technologies, such as capturing and then piping carbon dioxide from coal power plants into geologic rock formations, and (2) natural carbon sinks, such as forests and soil.

Human-engineered carbon capture and sequestration projects, such as injecting carbon dioxide into geological formations or the deep ocean, offer significant opportunities to remove carbon dioxide from the atmosphere. Although not widely practiced to date, geological sequestration appears feasible based on experience in the oil and natural gas industries. The basic approach is to inject carbon dioxide into underground rock formations and then permanently store the gas. The possibility of sequestering carbon dioxide in the deep ocean is also being studied and employed in limited situations. In this case, carbon dioxide emissions would be captured and then pumped deep in the ocean.

The benefits of engineered carbon capture and sequestration projects are that they would complement existing and proposed fossil fuel power plants, and that carbon dioxide would likely be trapped for thousands of years in the case of geological sequestration, or hundreds of years for deep ocean sequestration. Key weaknesses of such projects are that certain technologies for capturing the carbon dioxide emitted by burning fossil fuels are still in the developmental stage or are very costly. Further, employing these technologies decreases the efficiency of power plants because they require significant amounts of

[5] Carbon storage is commonly referred to as carbon sequestration.

energy to capture carbon dioxide from the emissions stream. Other weaknesses of geological sequestration include the lack of experience with such projects, the need to perpetually monitor sequestration sites, the lack of methods to monitor and repair leaks, the lack of a legal framework and regulatory structure, and the need to develop pipelines and other infrastructure to transport carbon dioxide from the source to the sequestration site. Despite recent studies suggesting great carbon storage potential, the weaknesses of deep ocean sequestration include the unknown impact on sea life, among other factors.

Natural carbon sinks sequester carbon dioxide already in the atmosphere. For example, plants remove carbon dioxide from the atmosphere as an input for photosynthesis and store it in plant matter, such as tree trunks. If plants that sequester large amounts of carbon (like certain species of trees) replaced plants that do not sequester large amounts of carbon (such as some crops), they could remove carbon dioxide from the atmosphere for a period of time, potentially hundreds of years. The key benefit of this approach is that it relies on natural processes. The drawbacks of natural sequestration are that the carbon is only trapped temporarily, and that it requires a large amount of land. For example, the U.S. would have to replace over half of the country's 968 million acres of farmland with very fast-growing trees by the end of 2006 in order to sequester 5.7 billion tons of carbon dioxide annually by 2020.[6] Even if all of this farmland could support such forests, other uses of such land may be more economically efficient and environmental or land-use changes could disrupt the productivity of such projects. Figure 2 below illustrates carbon sequestration options and policy considerations.

Figure 2: Carbon Dioxide Sequestration Options

Property	Terrestrial biosphere	Deep ocean	Geological reservoirs
CO_2 sequestered or stored	Stock changes can be monitored over time.	Injected carbon can be measured.	Injected carbon can be measured.
Ownership	Stocks will have a discrete location and can be associated with an identifiable owner.	Stocks will be mobile and may reside in international waters.	Stocks may reside in reservoirs that cross national or property boundaries and differ from surface boundaries.
Management decisions	Storage will be subject to continuing decisions about land-use priorities.	Once injected there are no further human decisions about maintenance once injection has taken place.	Once injection has taken place, human decisions about continued storage involve minimal maintenance, unless storage interferes with resource recovery.
Monitoring	Changes in stocks can be monitored.	Changes in stocks will be modelled.	Release of CO_2 can be detected by physical monitoring.
Expected retention time	Decades, depending on management decisions.	Centuries, depending on depth and location of injection.	Essentially permanent, barring physical disruption of the reservoir.
Physical leakage	Losses might occur due to disturbance, climate change, or land-use decisions.	Losses will assuredly occur as an eventual consequence of marine circulation and equilibration with the atmosphere.	Losses are unlikely except in the case of disruption of the reservoir or the existence of initially undetected leakage pathways.
Liability	A discrete land-owner can be identified with the stock of sequestered carbon.	Multiple parties may contribute to the same stock of stored CO_2 and the CO_2 may reside in international waters.	Multiple parties may contribute to the same stock of stored CO_2 that may lie under multiple countries.

Source: Intergovernmental Panel on Climate Change, *Carbon Dioxide Capture and Storage: Summary for Policymakers and Technical Summary*, (September 2005)

[6]This committee staff calculation is based upon the total acres of farmland in the U.S. in 2002 as reported in the 2002 Census of Agriculture by the National Agriculture Statistics Service, and the *Sequestration from Forestry Excel Workbook* and *Guidance for Reporting Sequestration from Forestry Activities* published by the Energy Information Administration (see http://www.eia.doe.gov/oiaf/1605/techassist.html).

Conclusion

Increasing the amount of electricity generated by nuclear power and renewable resources in combination with energy efficiency efforts appears preferable on a number of levels to other strategies. First, it is simpler to emit less carbon dioxide in the first place than to capture, transport, and store the gas after the fact. Although promising, the added complexity of carbon sequestration invites uncertainty and an increased risk of failure. Second, in contrast to the proven track record of nuclear and renewable technologies, significant uncertainties remain about the cost and viability of human-engineered carbon sequestration activities. For example, in 2004, the U.S. Climate Change Science Program stated that:

> "Enhancing carbon sequestration is of current interest as a near-term policy option to slow the rise in atmospheric CO2 and provide more time to develop a wider range of viable mitigation and adaptation options. However, uncertainties remain about how much additional carbon storage can be achieved, the efficacy and longevity of carbon sequestration approaches, whether they will lead to unintended environmental consequences, and just how vulnerable or resilient the global carbon cycle is to such manipulations." [7]

Third, the amount of land necessary to sequester significant amounts of carbon dioxide in forests and other natural systems is not feasible from a land management standpoint. For example, the U.S. would have to replace over half of the country's 968 million acres of farmland with very fast-growing trees by the end of 2006 in order to sequester 5.7 billion tons of carbon dioxide annually by 2020.[8] Even if all of this farmland could support such forests, it is very likely that other uses of the land are more economically efficient. Again, while a diverse range of approaches are necessary to fully rebalance the carbon cycle, reducing emissions by emphasizing nuclear power and renewable resources in conjunction with energy efficiency efforts makes the most sense because these technologies are more proven and reliable than other alternatives and they directly address the problem by emitting zero carbon dioxide.

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[7] U.S. Climate Change Science Program, *Our Changing Planet: The U.S. Climate Change Science Program for Fiscal Years 2004 and 2005*, (Washington DC, July 2004)

[8] This committee staff calculation is based upon the total acres of farmland in the U.S. in 2002 as reported in the 2002 Census of Agriculture by the National Agriculture Statistics Service of the United States Department of Agriculture, and the *Sequestration from Forestry Excel Workbook* and *Guidance for Reporting Sequestration from Forestry Activities* published by the Energy Information Administration of the Department of Energy (see http://www.eia.doe.gov/oiaf/1605/techassist.html).

Issues That Will Be Addressed By This Hearing

Panel 1 - What is the Federal Government Doing to Rebalance the Carbon Cycle?

- What is the federal government doing to learn about the carbon cycle?
- What is the federal government doing to reduce anthropogenic carbon emissions?

Panel 2 - Carbon Cycle Science

- What do and don't we know about the carbon cycle?
- How is the carbon cycle changing in the United States, and why?
- What is the potential significance of these changes?

Both Panel 1 and Panel 2

- What are the strengths and weaknesses of different technologies to reduce carbon emissions?
- How do federal government programs address what is and is not known about the carbon cycle?

Witnesses

Panel 1 - What is the Federal Government Doing to Rebalance the Carbon Cycle?

- **Mr. John B. Stephenson**
  Director, Natural Resources and Environment, Government Accountability Office
- **Dr. Roger C. Dahlman**
  Co-Chair, Interagency Carbon Cycle Working Group, Climate Change Science Program
- **Mr. Stephen D. Eule**
  Director, U.S. Climate Change Technology Program

Panel 2 - Carbon Cycle Science

- **Dr. Gregg Marland**
  Ecosystems Science Group, Environmental Sciences Division, Oak Ridge National Laboratory
- **Dr. Steven C. Wofsy**
  Abbott Lawrence Rotch Professor of Atmospheric and Environmental Chemistry, Harvard University
- **Dr. Daniel A. Lashof**
  Science Director, Climate Center, Natural Resources Defense Council

STAFF CONTACT

Larry Brady, Staff Director
Subcommittee on Energy and Resources
B-349C Rayburn House Office Building
202.225.6427 / 202.225.2392 fax